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Novel Method for Growing Te-Inclusion-Free CZT

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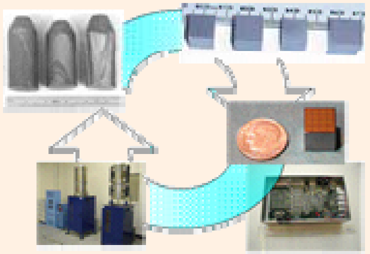


Research team and budget

Co-investigators: **G. Gu, A. Bolotnikov, G. Camarda, Y. Cui, A. Hossain, G. Yang, Brookhaven National Laboratory.**
Industrial sub-contractors: L. Li, Yinnel Tech, South Bend.
University sub-contractors: A. Burger, Fisk University, TN.
Other Universities: Fisk University, Tennessee Technological University, and Vanderbilt University

Budget: FY08: $457K, FY09: $450K, FY10: $450K

Project overview

We propose a new method for growth of detector-grade CdZnTe (CZT) with reduced concentration and sizes of Te inclusions. The method is designed to impede the formation of Te-rich inclusions in crystals due to the use of new CZT growth method and a unique ampoule design.

Relevance to the non-proliferation mission

Large CZT single crystals open new opportunities for room-temperature semiconductor detectors, even in areas traditionally dominated by scintillators (NaI and CsI) and liquid-nitrogen cooled Ge detectors. Large CZT detectors bring together the potential for high detection efficiency, good energy resolution, ambient-temperature operation and advantages of highly integrated electronics. Such improvements in radiation detector technologies are urgently needed by many agencies concerned with nuclear nonproliferation.

Prior work

Recently, we obtained direct evidence that Te inclusions are the major cause of the poor energy resolution of long-drift CZT detectors [1,2]. It was generally accepted that large-size inclusions, >100 μm, or aggregations of inclusions associated with other large-scale crystal defects, degrade device performance. But randomly distributed small-size inclusions were not seen as harmful. We used a high-spatial resolution X-ray mapping system utilizing a beam X27B at NSLS to determine correlations.

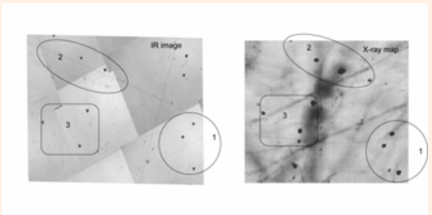


Fig. 1. Correlation between Te inclusions as identified by dark spots in the IR image and degraded zones displaying poor charge collection as seen in the X-ray map. The X-ray scan area is ~1.2x1.2 mm2, the beam size is 10x10 μm2, and the step size is 10 μm.

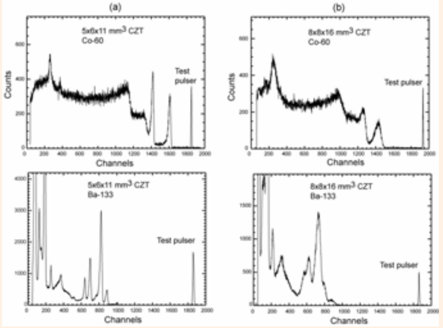


Fig. 2. The spectra on the left (right) is for the 10-mm-long virtual Frisch-grid detector with a relatively low (high) concentration of Te inclusions.

Our recent results helped us to gain valuable insight into the root cause of the problem associated with the performance degradation of large-volume CZT detectors.

Proposed work and scientific basis

Our goal is to modify the CZT growth processes with a focused goal of reducing or eliminating altogether the presence of Te inclusions. Two new methods for growth of detector-grade CdZnTe (CZT) with reduced concentration and sizes of Te inclusions will be investigated.

Floating zone method

The main advantages of this approach: eliminates crystal contact with a growth ampoule, provides better control over growth conditions, and improved mixing of the melt. The ingot size, <20 mm diameter, will need to be increased for commercial use.

Floating zone furnace at BNL

Low-pressure Bridgman method utilizing a unique ampoule design

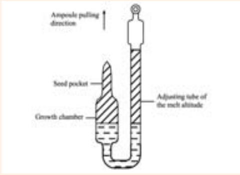
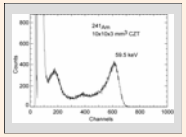


Fig. 3. Schematic diagram of the growth ampoule [3].

During the crystal-growth process, the seed pocket and the growth chamber of the U-type quartz ampoule will be filled with the CZT melt, and the long and thin section will also be filled with CZT melt. Because of the relatively high density of CZT, it is possible to remove the surplus space in the seed pocket by adjusting the height of the CZT melt. Thus, the decomposition of the CZT melt can be completely suppressed, and the evaporation of Cd can be prevented. Furthermore, the Te-rich clusters in the melt, which would normally sink and deposit at the liquid-solid interface of the growing crystal, will now sink away from the liquid-solid interface. When the U-type ampoule is pulled upward, the CZT crystal grows downward, and the directions of the crystal growth and the sinking of the segregated Te-rich regions are both in the downward direction. In this way the segregated Te-rich regions, which are continuously formed in the melt as Cd is lost to the vapor, sink away from the growing crystal and cause no instabilities in the growth process.

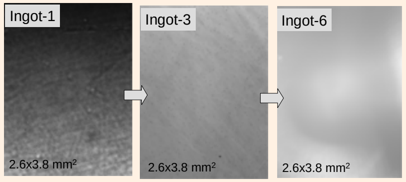
Progress to date

1. Using a floating zone method, we produced CZT with no inclusions with sizes > 2 μm, fair mu-tau product, $3x10^{-3}$ cm^2/V, and resistivity > 10^{10} Ohm cm.
2. We were able to control the size/concentration of Te inclusions by changing the growth parameters.



Reducing of growth rate

Illustration of Te inclusions reduction



3. We are working together with growth furnace manufacturers to design and build a low-pressure Bridgman furnace to accommodate the U-shaped ampoule.

Literature

[1] G. A. Carini, A. E. Bolotnikov, G. S. Camarda, G. W. Wright, L. Li, and R. B. James, “Effect of Te precipitates on the performance of CdZnTe detectors”, Appl. Phys. Lett. 88, p. 143515, 2006.

[2] G. S. Camarda, A. E. Bolotnikov, G. A. Carini, and R. B. James, “Effects of Tellurium Precipitates on charge collection in CZT Nuclear Radiation Detectors”, in Countering Nuclear and Radiological Terrorism, edited by S. Aprkyan and D. Diamond, Springer, 2006, pp. 199-207.

[3] Yi He, Shifu Zhu, Beijun Zhao, Yingrong Jin, Zhiyu He, and Baojun Chen, “Improved Growth of PbI2 Single Crystals”, J. of Crys. Growth, Vol. 300, Issue 2, pp. 448-451, 2007.

Acknowledgments

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